TP 6289E

german & milne inc.

Prepared for the
Transportation Development Centre
Transport Canada

March 1985

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TP 6289E

NAWS REPEATER

Hull Stress Monitoring System
Repeater Unit

Prepared for

Transportation Development Centre
Transport Canada

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German & Milne Inc.
Montreal, Quebec

March 1985

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REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP 6289E	6173	

4. Title and Subtitle	5. Report Date
NAWS REPEATER Hull Stress Monitoring System Repeater Unit	March, 1985
	6. Performing Organization Report No. 7138-R11
7. Author(s) B.G. Quart	8. Transport Canada File No. D 1460-166-43
9. Performing Organization Name and Address German & Milne Inc. 4999 Ste Catherine St. West, Suite 300 Westmount, Quebec H3Z 1T3	10. DSS File No. 11SD.T8200-3-3598
	11. DSS or Transport Canada Contract No. OSD84-00014
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 1000 Sherbrooke Street West,Suite 2421 Montreal, Quebec H3A 2R3	13. Type of Report and Period Covered
	14. Sponsoring Agency Code TDC 6173
15. Supplementary Notes	16. TDC Project Officer Jacques Laframboise

17. Abstract

Navigation of ships in ice relies heavily on the judgement and expression of navigating officers. The NAWS system (Navigation Aid for Working Stresses) is a microprocessor based instrument, which samples an array of strain gauges fixed to the hull of the vessel, and analyses the stress incurred on the ship's structure during icebreaking. The object of the system is to provide sufficient information on the ship/ice interaction to aid the officers operate the ship nearer its optimum design specifications.

The test and evaluation of the prototype system was carried out in August 1983. The system generated gratifying evaluation results from the Captain and crew. A major recommendation made by the officers was to make the visual information from the NAWS more readily accessible to the navigating officer.

A NAWS repeater unit was conceived, which performs the display functions of the master control unit, without any of the peripherals or system control functions. This unit was developed and installed on-board the CCGS PIERRE RADISSON, in order to provide the necessary information to the master, while minimizing the required space on the command console. The Repeater unit is now in operation aboard the CCGS PIERRE RADISSON.

18. Key Words	19. Distribution Statement
Response Monitoring System Hull Response monitor Instrumentation Icebreaking Arctic Marine Vessels	A limited number of copies are available from sponsoring agencies.

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
None	None	35	---

TDC CDT 79-005

FORMULE DE DOCUMENTATION POUR RAPPORT

1. N° du rapport Transports Canada	2. N° de l'étude — CDT	3. N° de catalogue du destinataire
TP 6289E	6173	

4. Titre et sous-titre	5. Date du rapport
NAWS REPEATER Hull Stress Monitoring System Repeater Unit	mars 1985
	6. N° du rapport de l'organisme exécutant 7138-R11
7. Auteur(s) B.G. Quart	8. N° de dossier Transports Canada D 1460-166-43
9. Nom et adresse de l'organisme exécutant German & Milne Inc. 4999 o., rue Ste Catherine, Suite 300 Westmount, Québec H3Z 1T3	10. N° de dossier — ASC 11SD.T8200-3-3598
	11. N° de contrat — ASC ou Transports Canada OSD 84-00014
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 1000 o., rue Sherbrooke, Suite 2421 Montréal, Québec H3A 2R3	13. Genre de rapport et période visée
	14. Code de l'organisme parrain CDT 6173
15. Remarques additionnelles	16. Agent de projet — CDT Jacques Laframboise

17. Résumé

La navigation dans une mer chargée de glaces fait largement appel à l'expérience et au jugement de l'officier navigateur. Le système NAWS est un instrument à base de microprocesseur qui interroge un arrangement de jauges de tension soudées à la coque du vaisseau, et qui analyse les forces subies par la structure pendant le bris des glaces. Le système NAWS (Navigation Aid for Working Stresses) modifie la navigation dans les glaces en mettant à la disposition de cet officier, l'information lui permettant d'exploiter le navire au plus près de ses capacités nominales.

Le programme d'essai et d'évaluation du prototype NAWS a suscité des commentaires favorables de la part du commandant et de l'équipage. Une recommandation majeure des officiers était de rendre les informations visuelles provenant du système plus accessibles à l'officier au poste de commande.

Une réplique du panneau d'affichage du système a été conçue, développée et installée à bord du NGCC PIERRE RADISSON pour répondre aux besoins mentionnés ci-haut. Cette réplique, appelée 'NAWS Repeater', est d'une largeur inférieure au système NAWS, permettant son installation sur la console de commande. Le 'NAWS Repeater' est présentement installé à bord du NGCC PIERRE RADISSON.

18. Mots-clés	19. Diffusion
Système réactionnel Détecteur des niveaux de contrainte Instrumentation Déglaçage Navire de cote arctique	Le CDT dispose d'un nombre limité d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
Aucun	Aucun	35	---

CDT/TDC 79-005

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ACKNOWLEDGEMENTS

The authors gratefully acknowledge the advice and assistance provided by the Master and crew of the CCGS PIERRE RADISSON. In particular captain Paul Pelland for his valuable evaluation of the NAWS System and his recommendations which led to the development of the repeater unit, and Captain Emile Lavoie for his assistance and comments during the development and installation of the system.

SUMMARY

This report details the research and development program undertaken by the Transportation Development Centre of Transport Canada for the design, manufacture and installation of a NAWS repeater sub-unit on board the CCGS PIERRE RADISSON.

Upon the initial test and evaluation of the NAWS hull stress monitor, several recommendations were expressed by the master and crew of this vessel as to valuable modifications possible to the system. The primary complaint of the Master was his inability to actually observe the system while at his navigating post, thereby relying on information relayed to him from a member of the crew observing the system at the navigating chart console. In order to make the information more readily accessible to the master it was proposed that a mimic of the graphic display portion of the NAWS system be developed and installed at a location more convenient to the master.

A "repeater" sub-unit was viewed as being a means of providing only that information necessary to the navigating officer, while keeping the non-essential system functions at the master control unit on the navigating chart console.

The repeater unit also embodies another recommendation of the crew, namely the extension of the bar chart stress indicators into the red and yellow regions. This allows the observer to evaluate precisely where within each of the levels a specific stress sample may lie.

The Repeater unit is now installed adjacent to the telegraph command, on the navigating bridge and is readily visible to the master while at the conning position.

SOMMAIRE

Ce rapport décrit les détails du projet de recherche "Design & Installation of a NAWS Repeater Unit", entrepris par le Centre de développement des transports (CDT), Transports Canada.

Suite au programme d'essai et d'évaluation du prototype du système NAWS à bord du NGCC PIERRE RADISSON, plusieurs officiers ont donné leurs avis sur le fonctionnement du système. Certains d'entre eux, se plaignaient sur l'inaccessibilité des indications provenant du NAWS à l'officier navigateur situé au poste de commande. Cette lacune lui l'obligeait à compter sur les renseignements transmis par un membre de l'équipage observant le panneau d'affichage du système.

Dans le but d'améliorer l'accessibilité du système, il a été proposé de créer une réplique du panneau d'annonciateurs de l'unité de commande. Cette réplique ou "REPEATER", sera identique au panneau de NAWS, mais de taille réduite pour faciliter l'installation dans un endroit plus à la portée du commandant pendant qu'il éxecute ses tâches de navigateur. Ce "REPEATER" a été construit afin de munir l'officier navigateur avec seulement les informations d'intérêt, en gardant tous les contrôles du système à l'unité de commande située sur la console des cartes.

En conformité avec les opinions des membres de l'équipage interviewés durant le programme d'évaluation, le domaine de fonctionnement des colonnes lumineuses à été agrandi pour embrasser les zones rouges et jaunes. Ceci permet à l'observateur d'évaluer précisément un niveau de contrainte par rapport aux zones principales (c'est à dire, vertes, jaunes et rouges).

Le "REPEATER" est présentement en opération à bord du NGCC PIERRE RADISSON, où il sert à fournir les indications pertinentes sur l'action réciproque navire/glace, au navigateur à son poste de commande.

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1.0 INTRODUCTION

The concept of a NAWS Hull Stress Monitor was initiated through an unsolicited proposal to TDC (Transportation Development Centre, Transport Canada) in April 1981. Since that time, two generations have been designed, built and installed under contract to TDC by German & Milne Inc. of Montreal.

The NAWS instrument initiates a new concept in the field of ice navigation, serving to provide the Captains of ice going vessels with an instantaneous evaluation of the vessels responses to the ambient ice conditions. This type of feedback is seen as being beneficial to the master by aiding him/her navigate the vessels nearer its optimum design conditions. This avoids the possibility of damage to the hull structure while also enhancing the efficiency of the vessel, by allowing the master to operate at optimum speeds for given conditions of ice and/or sea state.

At present, ice navigating officers rely on their good judgement and familiarity with a given vessel to guide them safely and efficiently though treacherous ice filled waters. This requires the officers identify the type, age, thickness and content of the ice encountered and then estimate its prospective strength. Due to the typical non-homogeneous nature of ice floes, coupled with operational distractions and visibility restrictions, these decisions are often quite difficult to perform accurately. The response feedback provided by the NAWS system coupled with the expertise of a seasoned ice navigator provides an enhanced evaluation of the ship/ice interaction. It must be appreciated, however, that the NAWS system serves as a supplement rather than a substitute for the abilities of an experienced ice navigator.

The information presented by the NAWS system, may be used to expose trends in the stresses experienced by the hull structure. In order for the master to absorb adequate information to form his evaluation of the ice strength, the NAWS data must be readily available to him while navigating the vessel. Initial test and evaluation programs on board the CCGS PIERRE RADISSON illustrated this point. The prime recommendation of the master was to install the system at a location providing a better view to the officer navigating the vessel. The master control unit including the printer and keyboard, is quite bulky and provides many system control functions, not necessary to the master during the operation of the vessel. In addition, the available space on the command console is typically quite limited. It was proposed by German & Mile Inc., on the basis of recommendations included in the captain's evaluation, that a smaller mimic of the NAWS graphic stress indicator panel, be designed for installation on the command console. This "repeater" was to provide only that

information necessary to the master, while leaving system control and hardcopy to the master control unit installed on the chart console.

2.0 SYSTEM DESCRIPTION

The NAWS hull stress monitor is a microprocessor based instrument designed to monitor forebody stresses in icebreaking vessels. The system relies on a dedicated array of strain gauges fixed to the hull of the vessel to sense the stress experienced by the hull structure. The data is digitized, coded and transmitted to the bridge where an L.E.D. display indicates the point(s) of stress on the hull to the operator. Stress readings are categorized into three levels; RED for high stress values (i.e. >80% of yield stress), YELLOW for intermediate stresses (50%-80% of yield), and GREEN for those readings judged to be safe (>50% of yield).

Should any gauge exhibit stress readings in the RED region, an audible tone will sound, alerting the officers of the condition.

The NAWS system consists of three (3) basic units:

1. THE STRAIN GAUGE ARRAY

2. THE REMOTE SENSOR UNIT

3. THE MASTER CONTROL AND REPEATER SUB-UNIT

2.1 Strain Gauge Array

The NAWS strain gauge array performs the critical task of translating mechanical stress into electrical signals suitable for processing by the NAWS system. The NAWS strain gauge array consists of thirty-two or more gauges deployed at points of maximum risk on the hull structure. These points are determined through a structural analysis of the hull structure.

2.2 Remote Sensor Unit

The remote sensor unit performs the acquisition of data for the NAWS system. This unit is located in the proximity of the sensors. The strain gauges are terminated in the remote sensor unit, where they are sampled by the system at a minimum rate of 75 samples/sec. per sensor. The strain signals are amplified, filtered, and multiplexed through an analog/digital conversion stage.

Upon request from the master control unit, the remote sensor transmits the maximum value collected for each sensor since the unit was last interrogated. A mean value is retained for each sensor, and is used as a reference when calculating stress excursions. This eliminates errors due to offsets initiated by drift of the sensor signals. Should any sensors be found to exhibit mean values out of the acceptable range of operations of the sensor, that sensor is removed from the sampling pattern. A printed record is produced each time a sensor is declared inoperational. Information is transmitted to the master control unit in serial fashion along an EIA TYPE RS-422 serial interface. The data bus consists of a single twisted pair cable. up to eight remote units may reside on the bus simultaneously, each with a processing capacity of sixty four (64) channels. A maximum system configuration would therefore comprise 512 discrete sensor channels.

2.3 Master Control Unit and Repeater Sub-Unit

The master control unit and repeater sub-unit are installed on the navigating bridge. The master control unit performs all the system control tasks, displays data for the operator and provides hardcopy of significant stress events. A keyboard is included on the master control for user input into the system (see Figure 1). The repeater sub-unit is installed at the command console and mimics the display portion of the master control (see Figure 2).

The display assemblies on both units are similar providing a diagrammatic representation of the hull structure at the icebreaking waterline. Colored indicators are placed beneath the diagram and are illuminated when appropriate levels in that area of the structure are exceeded. Red lamps indicate stress readings in excess of eighty (80%) percent of the yield strength of the hull material, yellow lamps indicate readings in the fifty (50%) to eighty (80%) percent range, and green indicates that all the levels in the array lie below 50%. Green signals are shown only on the bar graph indicators, at the centre of each hull diagram. The bar chart indicator on the Repeater was designed to incorporate the yellow and red levels, thereby providing an indication of the exact position of a given stress reading within these stress levels. When stress readings exceed the green range, the bar chart on the NAWS unit is disabled, however, on the repeater the tri-coloured bar chart is always in operation.

Whenever a stress sample is found to lie in the red range, an audible tone accompanies the illumination of the red indicators on the master control and repeater sub-unit. This alarm may be disabled at any time by depressing the alarm enable/disable switch on the appropriate unit. On the

master control, a green status indicator adjacent to the switch indicates the status of the alarm, when illuminated, the alarm is disabled. On the repeater sub-unit, a switch in the upper right corner will enable/disable the alarm signal for this unit. Note that each unit has its own separate alarm, and each must be enabled/disabled separately. The repeater sub-unit also includes a switch to enable/disable the bar chart indicator (lamps), along with a power switch which allows the repeater to be disabled completely without affecting the operations of the NAWS system.

A printer is mounted on the front panel of the NAWS master control. This provides the operator with a hardcopy printout of any significant stress readings (i.e. >50% of yield). The printout provides the time of the stress reading, the area of the ship where the impact occurred, the exact gauge number were the impact occurred, and the magnitude of the stress as a percentage of the yield stress of the hull material. The magnitude is printed in one of two columns, readings which lie in the yellow range are printed in the left column, while those which lie in the red region are printed in the right. As with the alarm, the printing unit may be enabled/disabled by means of a switch on the NAWS master control front panel. The status indicator next to the switch indicates the status of the printer; when illuminated, the printer is disabled. A series of relevant status messages are provided on the printing unit for the operator. In the event that a gauge is declared inoperative the sensor is removed from the sampling pattern and a printed message indicating the sensor number is provided for the operator. A complete listing of all inoperative sensor is also available as a system status report. In the event of a power failure at the remote sensor unit, a message is printed indicating the time the unit went off-line. When power is restored, another message is printed providing the time when the system returned on-line.

3.0 REPEATER SUB-UNIT

The repeater sub-unit was developed as a result of recommendations made following the test & evaluation program performed on the CCGS PIERRE RADISSON. As mentioned, the repeater unit provides only the information of interest to the officer navigating the vessel. The repeater unit is a reduced version of the master control display assembly, providing stress displays, without any of the system control functions, or peripheral devices. The reduced size of the unit makes it more suited to installation on the command console. The repeater sub-unit requires absolutely no user input to function, however several modes of operation are selectible using the repeater panel switches. These switches allow the operator to choose alarm status (on/off), bar chart status (on,off);, and repeater status (on/off).

3.1 Repeater Hardware Design

The repeater unit is linked to the master control via a 25 conductor parallel data bus. Communications between the units are based on a master-slave type protocal, and communications between the units is uni-directional from the Master control to the repeater unit. The hardware design philosophy was to parallel the design of the display portion of the NAWS master control unit as closely as possible, thereby minimizing the necessary software modifications. The hardware in the repeater comprises two circuit boards (the repeater logic decoder, and the repeater L.E.D. board), the lexan front faceplate, and a +5v power supply.

The Repeater logic decoder, serves to receive data signals from the master control unit, decode this data into signals used to illuminate the appropriate lamps, and retain this information until the next update. The L.E.D. board comprises the coloured indicators, bar charts and numeric displays. Both boards are designed to interconnect using a sandwich type of assembly. (see Figure 3).

3.1.1 Repeater Logic Decoder

The repeater logic decoding card deciphers the signals from the master control unit, and updates the appropriate lamps on the repeater L.E.D. board. The input signals are buffered and latched using three SN74LS241 octal line drivers/receivers (U31, U32, U33) (see Appendix A; Schematic 7186-01). Eight input lines are dedicated to the signals for the lamps and bar charts, eight input lines are used for numeric display information, five lines are reserved for control

signals to the logic circuitry, and one for the audio alarm trigger. The signal for the lamps and bar charts are output on I/O port D of the NAWS master control microcomputer, those for the numeric display signals are multiplexed on I/O port E, and the control signals are output on I/O port B.

The signals for the lamps and bar charts are decoded using two 74LS138 1 of 8 binary decoding chips (U11, U12), and ten (10) SN74259 eight bit addressible latches (U1 - U10). Output signals on lines pd0, pd1, pd2, pd7 are buffered using a SN74S344 octal buffer (U13), to provide the necessary fan-out. Lines pd (0-4) are used to select the lamp channel. Each lamp requires two channels be switched on to illuminate it fully. Line pd5 selects lamp colour (0-red, 1-yellow). Line pd6 selects lamps or bar chart (0-lamps, 1-bar chart). Line pd7 describes status of the lamp/bar chart element selected (1-on/1-off). Line pb4 is used to strobe the decoders, once a valid address is placed on line pd (0-7).

Lines pE (0-7) are used to drive the seven segments of the numeric displays on the repeater unit. The signals for the three digits are multiplexed on these lines, and latched using three SN74S373 octal latches (U14-U16). The eight bit latches for each digit are controlled by lines pb1, pb2, pb3. The trigger for the audio alarm is transmitted on line pb7, and fed to a retriggerable monostable multivibrator chip with a pulse width set at .5 sec.

Current limiting resistors are included for each L.E.D. output. Networks are used, each comprising eight independent resistors, in a sixteen pin dip package (U18-U30). The resistance values of each package vary depending on the efficiency of the L.E.D.'s to which thy are connected. Exact values may be obtained from the parts lists and schematics (see Appendix A).

3.1.2 Repeater L.E.D. Board

The repeater L.E.D. board holds the lamps for the display assembly. The stress lamps are arranged to line up beneath the hull cross section diagram, when mounted beneath the lexan front panel. Due to the critical placement of the lamps and the reduced size criteria of the repeater unit, the lamps and decoding circuitry were separated onto two distinct boards, unlike the NAWS unit where both are on the same circuit board. In order to accommodate the large number of signals necessary between the two repeater boards, a sandwich type interconnection scheme was utilized, in which the two boards virtually mate together as one assembly. This packaging provided a compete circuit assembly less than three cm deep, while accommodating one hundred and twenty

interconnections between the boards (see Figure 3).

The repeater L.E.D. board comprises twelve yellow, and twelve red stress indicators, three green seven segment numeric displays, and three ten element bar charts (one red, one yellow and one green). The bar charts are arranged in a totem pole fashion, with the green on the bottom, yellow in the middle, and red on the top (see Figure 2).

Each stress indicator lamp is comprised of four distinct L.E.D.'s per package. In order to drive these lamps using TTL type outputs, only two L.E.D.'s is series per indicator are driven by a single output channel from the logic card. In order to fully illuminate a coloured section, it is, therefore, necessary to turn on two channels of the decoding circuitry.

Each element of the bar charts comprise only one L.E.D. and one channel is sufficient to drive each element. The seven segment displays each require eight signals per digit. These signals are multiplexed on the logic board and latched onto three eight bit buffers. Each buffered output line drives only one segment.

3.1.3 Repeater/Master Control Interface

The data bus between the master control unit and the repeater sub-unit comprises a twenty five conductor cable of approximately ten metres in length. In order to drive the TTL level output signals from the master control to the repeater unit, a line driver/receiver type of interface was used. Receivers were included on the circuit boards of the repeater, and a separate interface card was developed to drive the signals from the master control. The interface card plugs directly into the master control microcomputer card connector J2, and buffers the signals from ports D and E and some signals from port B. The interface uses three SN74S241 octal line drivers. Twenty-one output signals are buffered by the interface, the data bus also carries a system ground between the units. Only twenty-three of the available twenty-five lines are used. The interface was prototype design and is wire wrapped on a prototype board.

3.2 Repeater Software Design

3.2.1 Description

The NAWS repeater sub-unit is a peripheral device of the master control unit. The repeater does not contain any processing capability, and relies on the master control for the transmission of

necessary data and control signals.

In order to accommodate the addition of a repeater unit on the NAWS system, it is necessary to modify the master control software to perform the transmission of data to the repeater. The software for the remote sensor unit functions independently of the master control and is, therefore, not affected by the addition of the repeater unit.

As the repeater unit basically mimics the graphic display of the original NAWS unit, simple modifications to the routines for the illumination of stress lamps were performed. This entailed outputting data to the repeater, while the same data was being output to the master control display assembly. The repeater unit provides bar charts for each of the three stress levels (i.e. red, yellow and green). This option was not available on the original NAWS system and, therefore, required new algorithms be written. The modified flowcharts for the updated master control software is included in Appendix B.

The output ports used to provide signals to the repeater sub-unit are those used for communication to the HP-IB data acquisition device. Evidently both these options can not be included simultaneously in the system. The algorithms for connection of a data acquisition system remain in the system software, however, they are not used when a repeater sub-unit is installed.

3.2.2 I/O Structure

Data transmitted to the repeater unit is done in parallel form, on three output ports on the master microcomputer. The structure for the I/O ports used by the repeater unit is as follows:

Port D0 - channel select
D1 - channel select
D2 - channel select
D3 - channel select
D4 - channel select
D5 - colour select
D6 - lamp/bar chart select
D7 - on/off select

PORT E0 - segment a
E1 - segment b
E2 - segment c
E3 - segment d
E4 - segment e
E5 - segment f
E6 - segment g
E7 - segment dp

PORT B1 - latch character 1
B2 - latch character 2
B3 - latch character 3
B4 - strobe repeater lamps and bar chart
B7 - repeater alarm trigger

4.0 INSTALLATION

The installation of the NAWS repeater sub-unit was carried out in Quebec city by German & Milne Inc. personnel between January and March 1985.

The NAWS repeater sub-unit was installed on the command console of the CCGS PIERRE RADISSON, at the location indicated by the master as being the most convenient. A twenty-five conductor data bus interconnecting the master control and the repeater, was run under the bridge deck, along existing cable trays in the false deck bottom. Power requirements for the repeater unit were not readily available at the installation site, therefore, a power cable was run from the master control unit to the repeater along the same route as the data bus.

A subcontract was awarded to Talbot Hunter of Quebec city for the piercing of the command console and mounting of the repeater sub-unit onto the cosole.

Modifications to the master control unit included the installation of a gland through the master control enclosure for the data bus, fitting of the interface card to the master microcomputer card and the reprogramming of the eprom chips. Reprogramming was performed on-site with the aid of an apple IIe micro-computer. This was performed by German & Milne Inc. personnel on board.

Integration of the repeater into the NAWS system was performed by German & Milne Inc. engineers. The operation of the system was discussed briefly with the crew members. A revised version of the operator's manual and instructions was prepared and forwarded to the master.

The wiring diagrams and installation diagrams for the NAWS repeater installation in the Navigating Bridge are included in Appendix C.

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Montreal

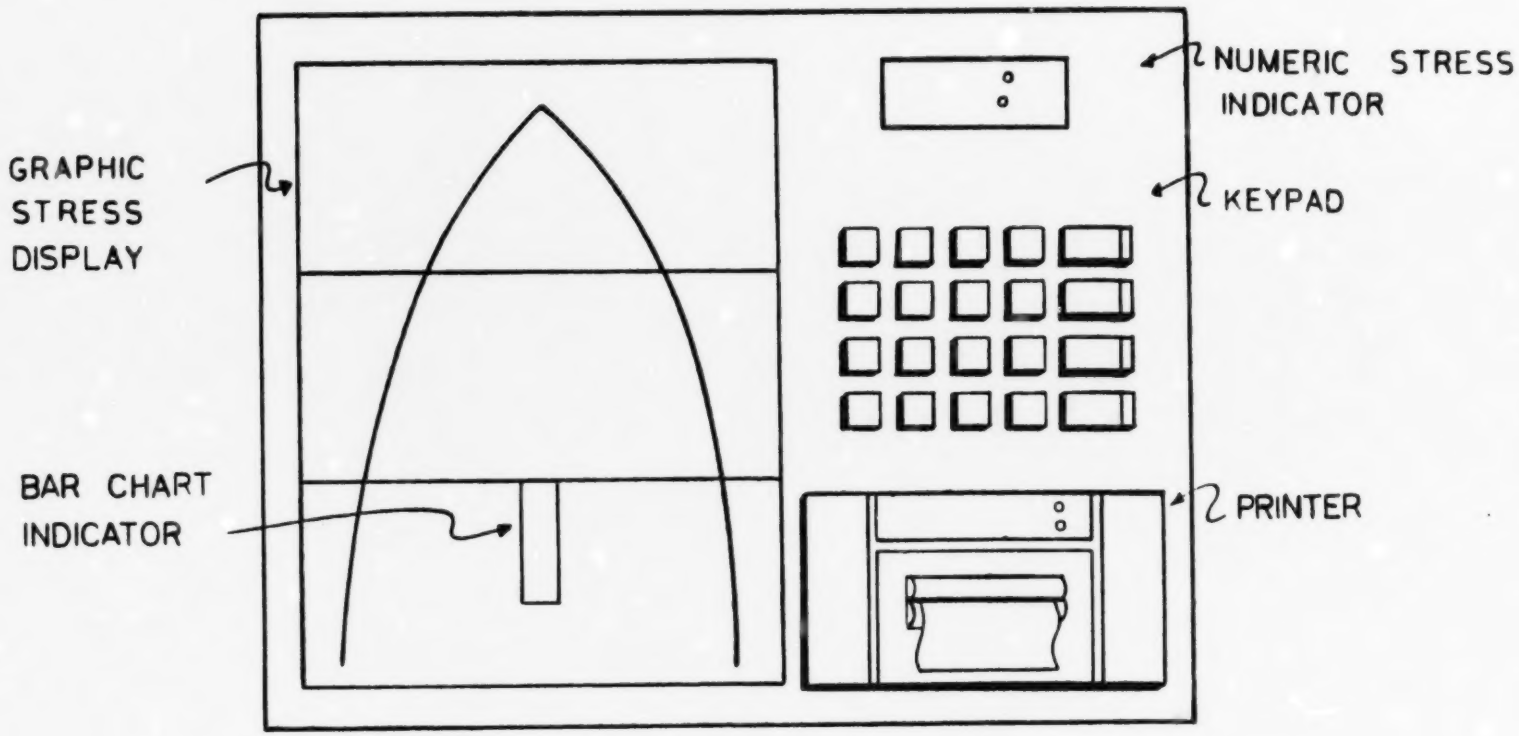
NEXT HIGHER ASSY.

TITLE
NAWS MASTER CONTROL UNIT

DWG. NO.
7138/04

DRAWN BY

DATE



NAWS MASTER CONTROL

FIGURE 1

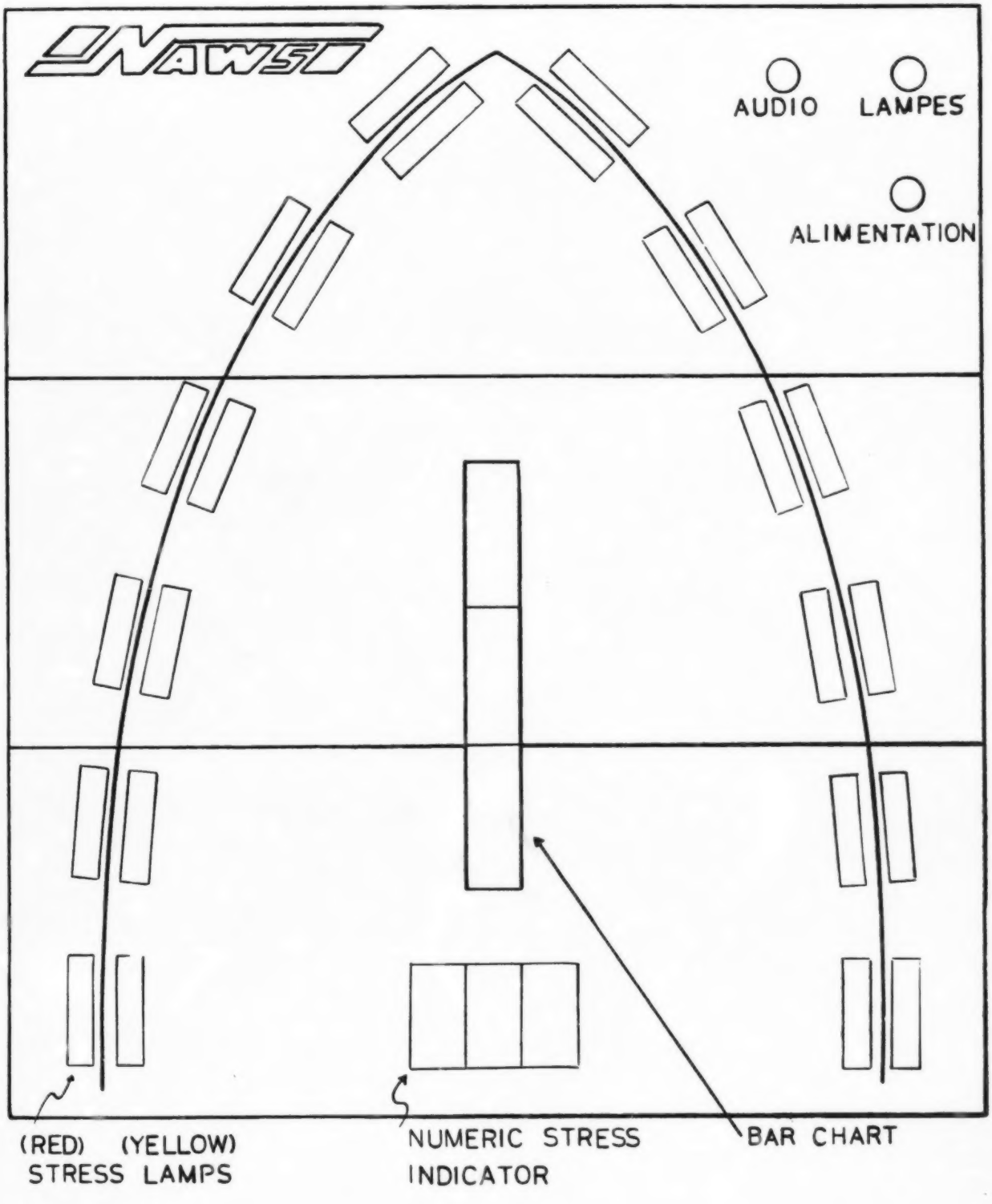


FIGURE 2

german + milne Marine Transportation Consultants Naval Architects Montreal	NEXT HIGHER ASSY.	DATE DRAWN BY
	TITLE NAWS REPEATER PANEL	DWG. NO. 7138/05

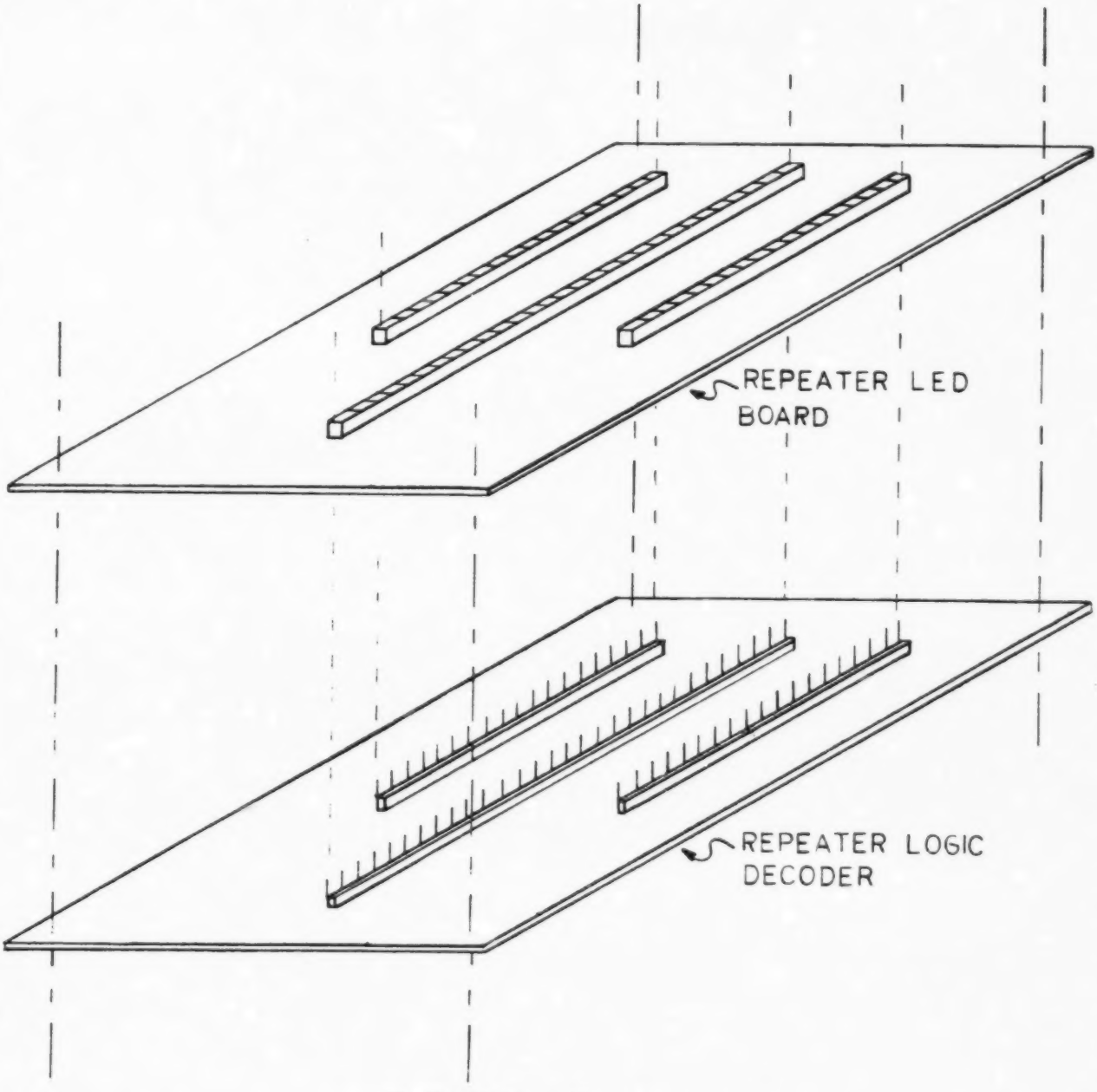


FIGURE 3

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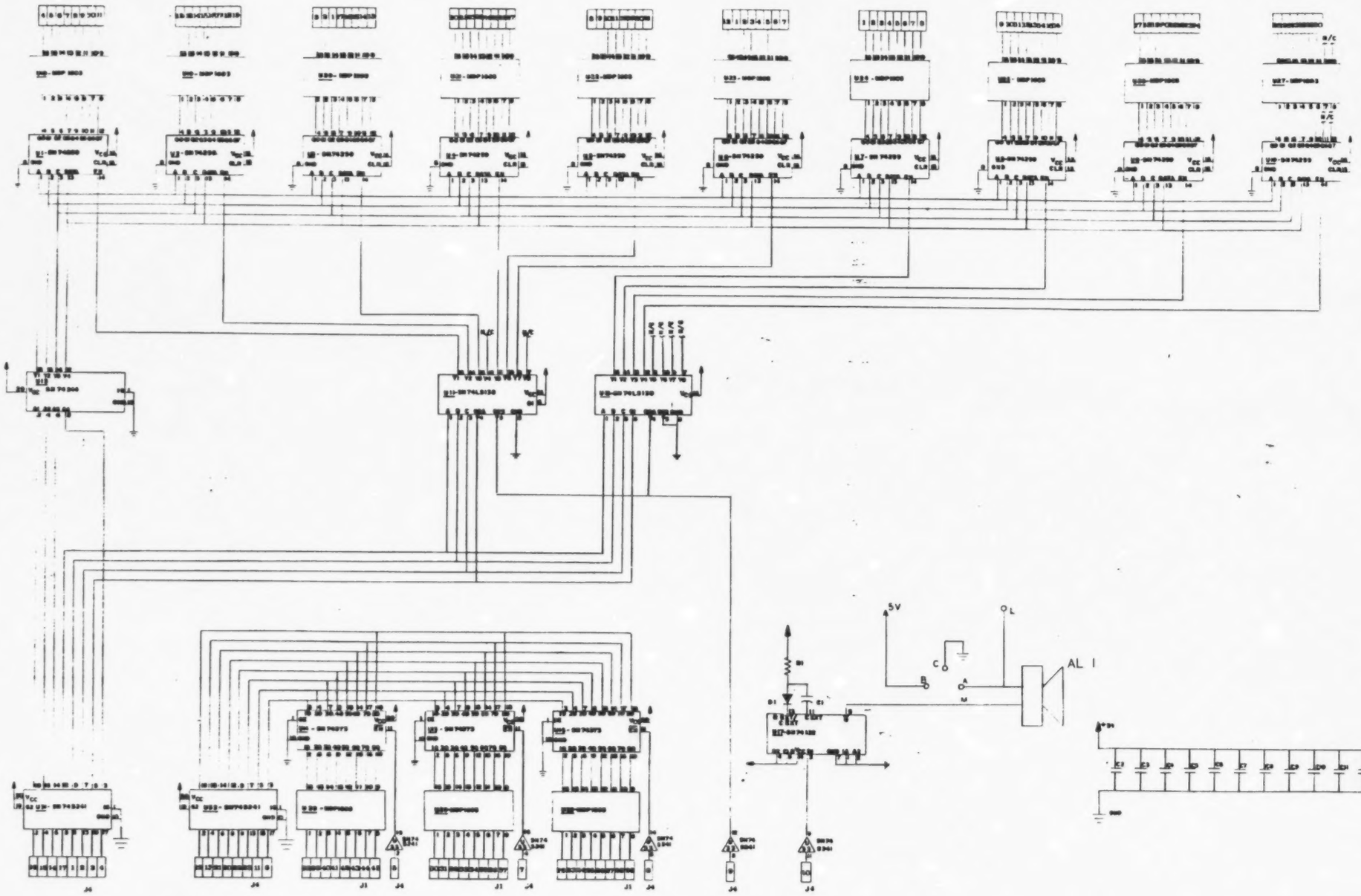
	TITLE REPEATER ASSEMBLY	DWG. NO. 7138/03

APPENDIX A:

Schematics for Repeater Hardware



german + milne Marine Transportation Consultants Naval Architects Montreal	NEXT HIGHER ASSY.	DATE OCT. '80
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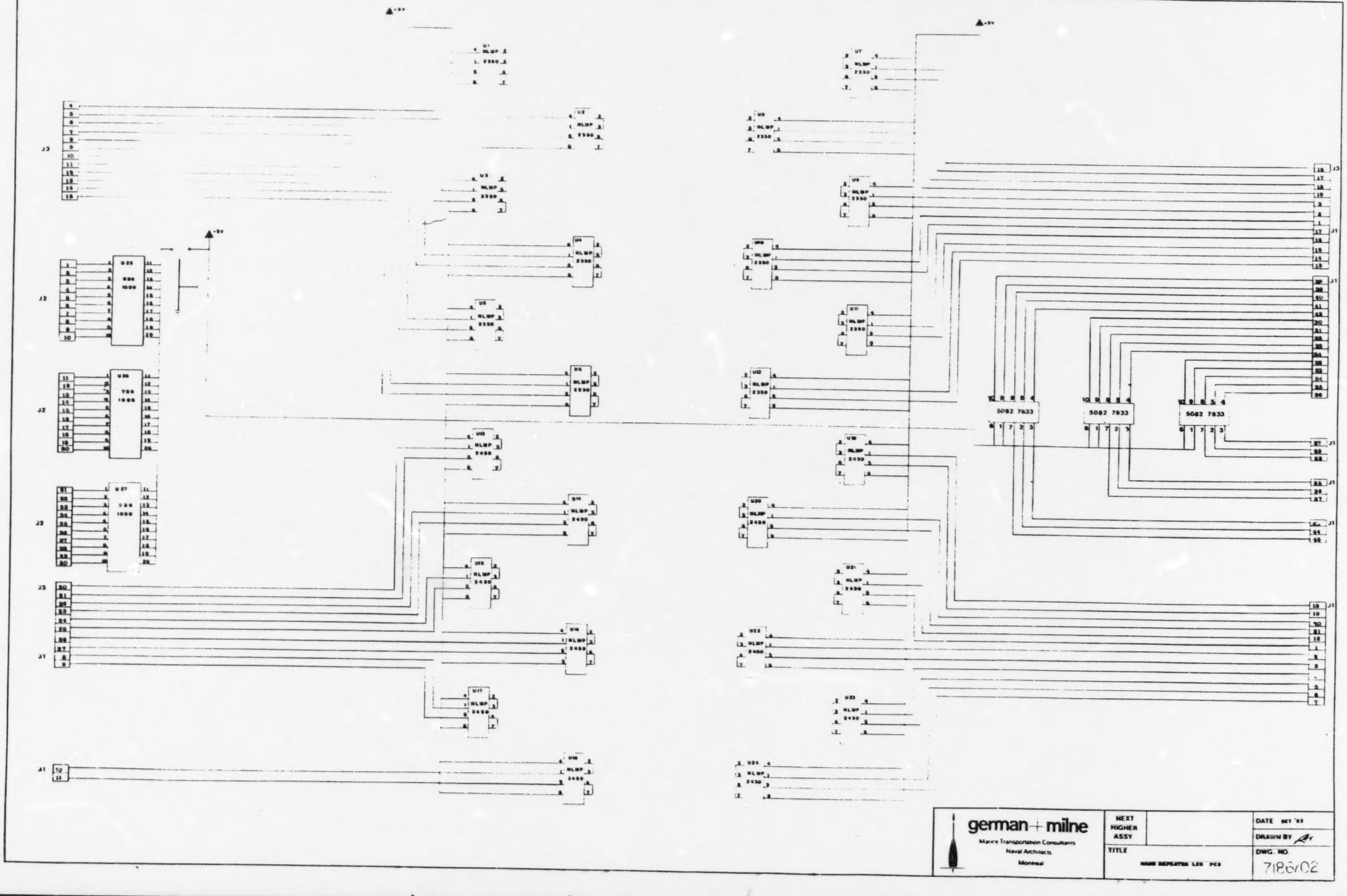
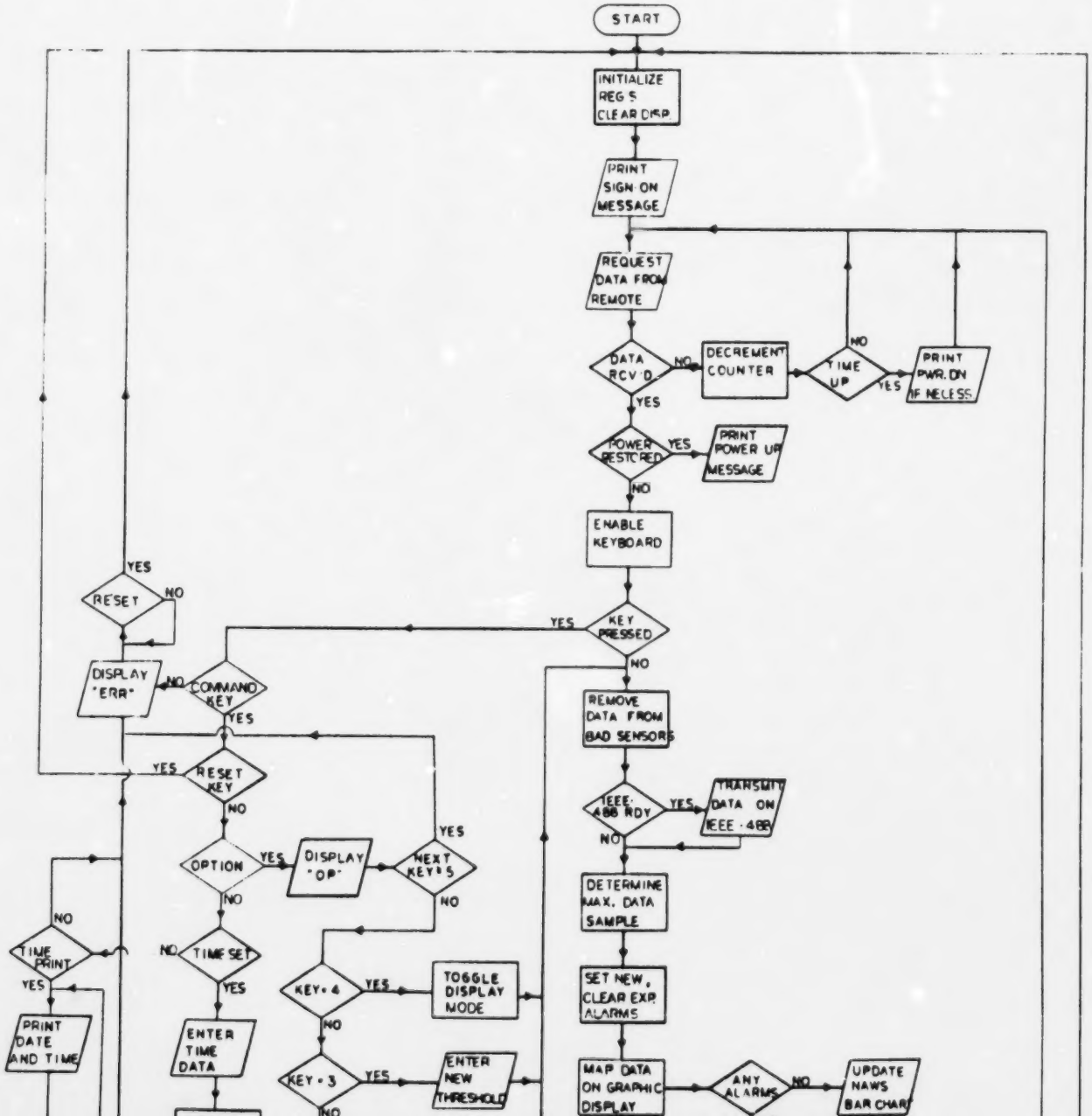
	TITLE RADIO REPEATER LOGIC U.S.S.	DWG. NO. 7138 - 01

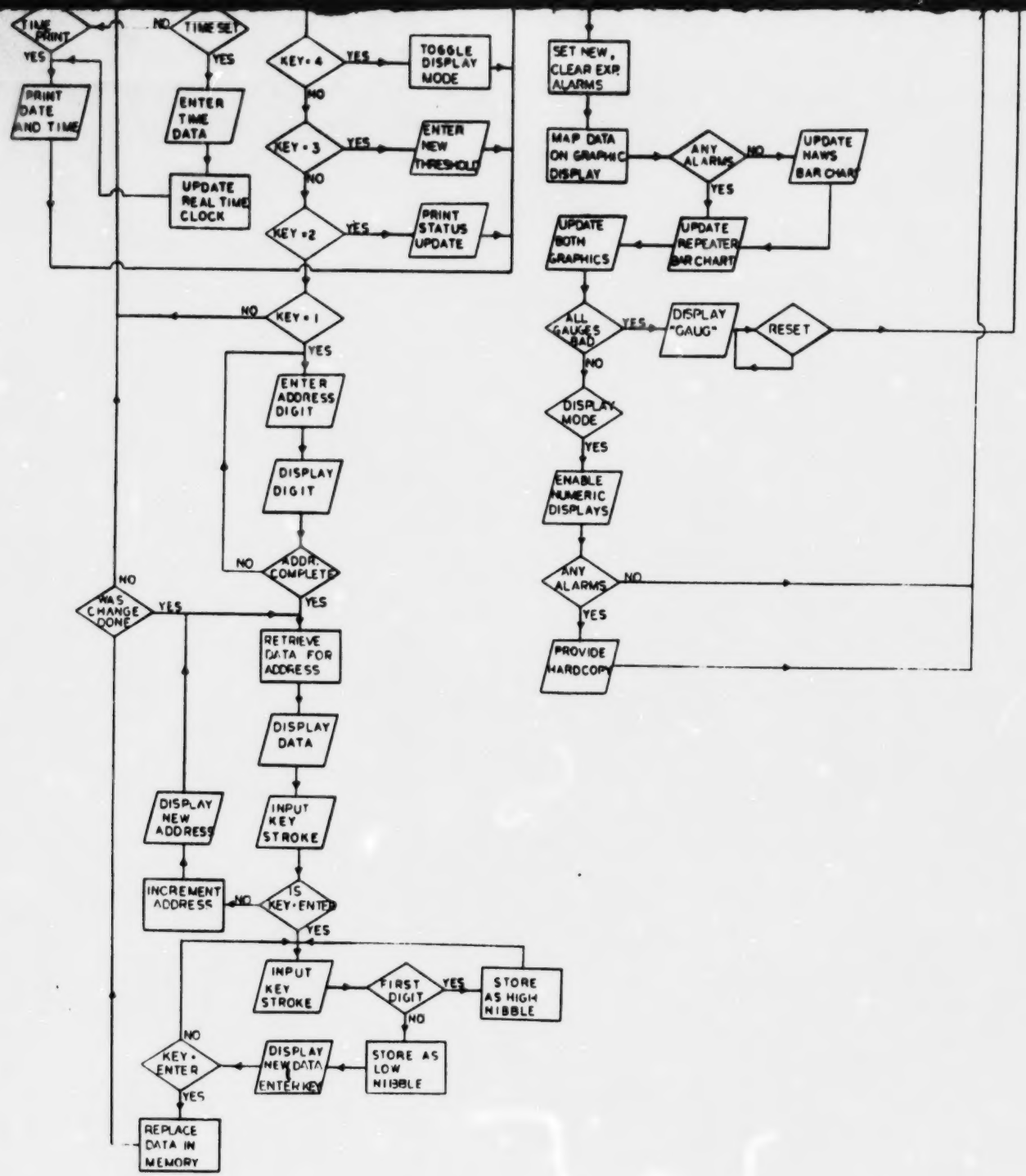


german + milne Marine Transportation Consultants Naval Architects Montreal	NEXT HIGHER ASSY	DATE OCT '83
	TITLE	DRAWN BY
		DWG. NO. 7186/02

APPENDIX B:

Software Flowcharts


START
INITIALIZE REGS CLEAR DISP
PRINT SIGN ON MESSAGE
REQUEST DATA FROM REMOTE
DATA RCV'D
NO
DECREMENT COUNTER
TIME UP
YES
PRINT PWR. DN IF NECESS.
YES
POWER RESTORED
YES
PRINT POWER UP MESSAGE
NO
ENABLE KEYBOARD
KEY PRESSED
YES
NO
RESET
YES
NO
DISPLAY "ERR"
NO
COMMAND KEY
YES
REMOVE DATA FROM BAD SENSORS
RESET KEY
YES
NO
IEEE 488 RDY
YES
TRANSMIT DATA ON IEEE-488
NO
OPTION
YES
DISPLAY "OP"
NEXT KEY IS
YES
NO
DETERMINE MAX. DATA SAMPLE
TIME PRINT
NO
YES
TIME SET
NO
YES
KEY = 4
YES
TOGGLE DISPLAY MODE
NO
SET NEW, CLEAR EXP. ALARMS
PRINT DATE AND TIME
ENTER TIME DATA
KEY = 3
YES
ENTER NEW THRESHOLD
NO
MAP DATA ON GRAPHIC DISPLAY
ANY ALARMS
NO
UPDATE NAWS BAR CHART



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Naval Architects
Montreal

NEXT HIGHER ASSY.

TITLE
MASTER CONTROL SOFTWARE FLOWCHART

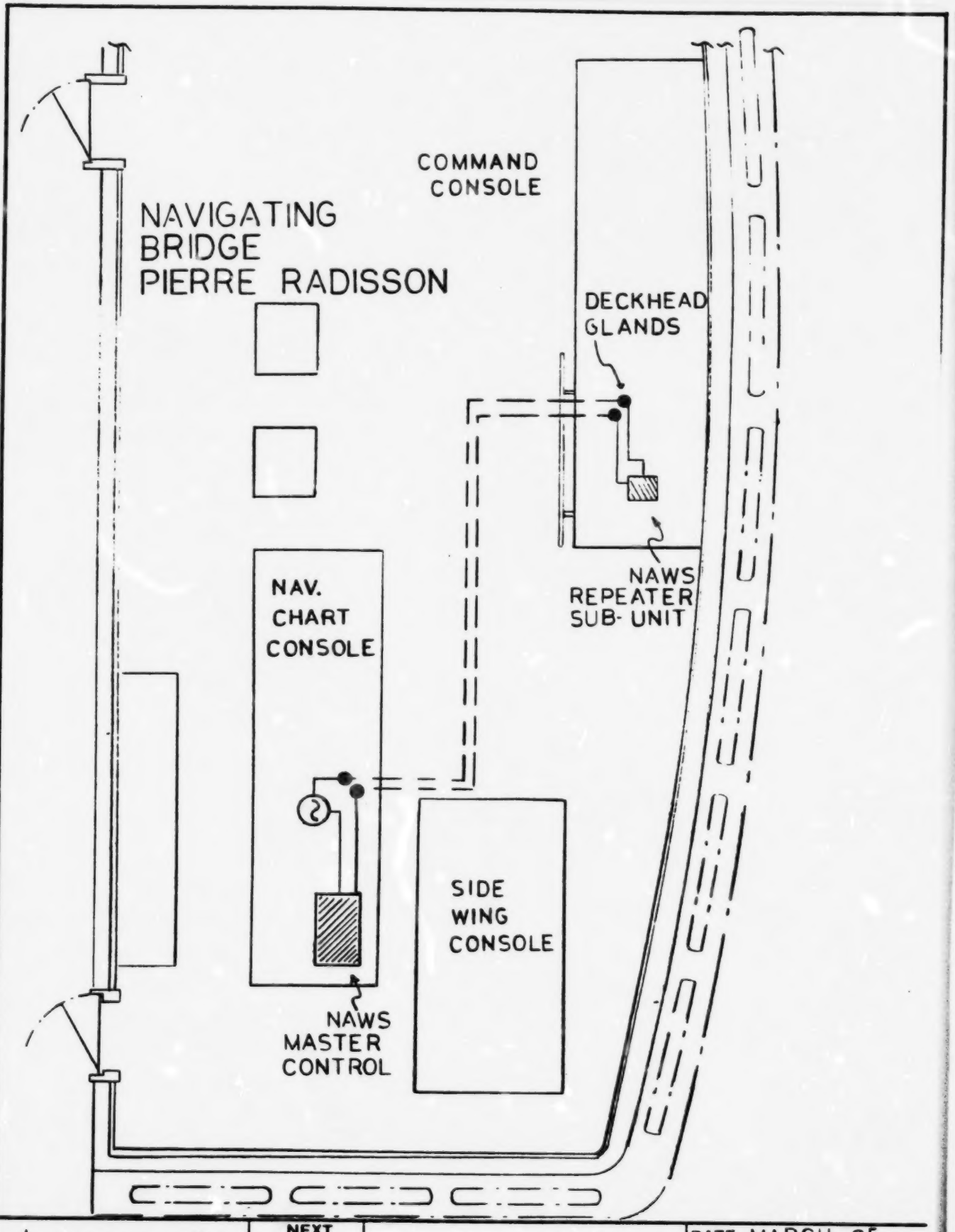
DWG. NO.
7138/06

DRAWN BY

DATE MARCH 85

APPENDIX C:

Installation and Wiring Diagrams



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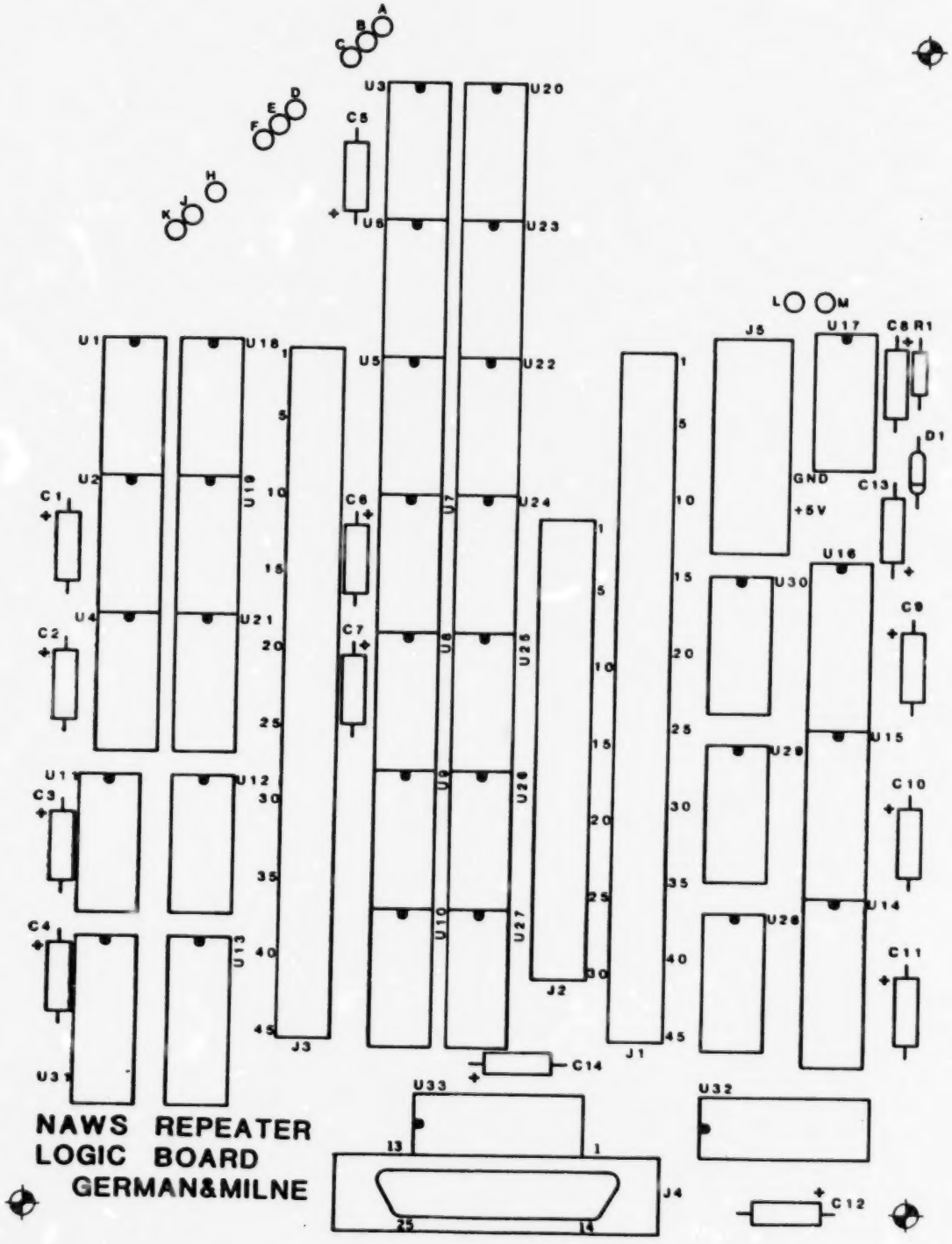
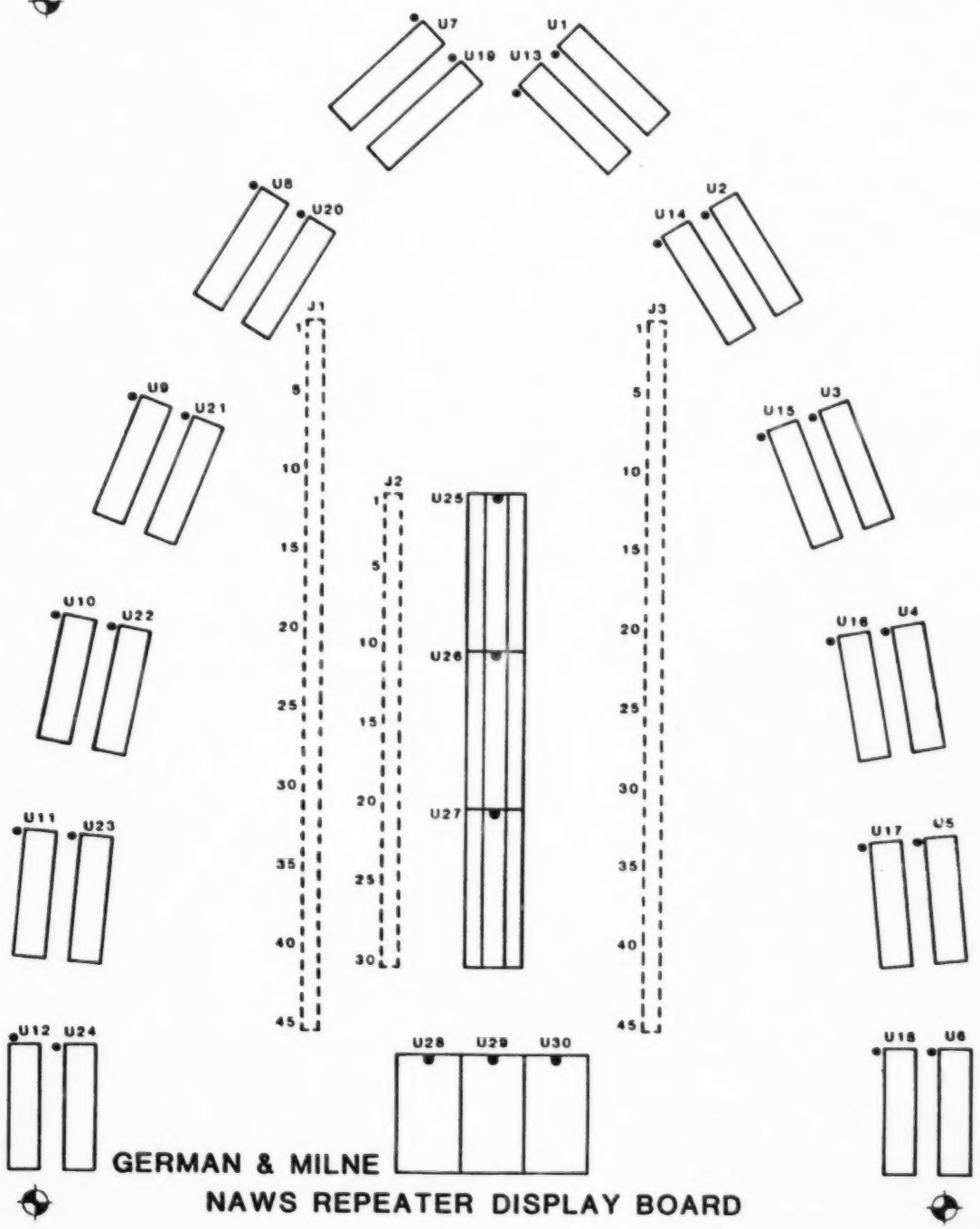
	TITLE NAWS REPEATER INSTALLATION	DWG. NO. 7138/07

APPENDIX D:

Component Layout of PCB



COMPONENT LAYOUT



COMPONENT LAYOUT

APPENDIX B:

Parts List

PARTS LIST

NOAA Repeater Logic Decoding PCB

Circuit Designation	Component Description	Part No.	Manufacturer	Qty.	Mil-Spec.
U1-U10	8 bit addressable latches	SN74259	Texas Instruments	10	
U11-U12	1 of 8 binary decoder	SN74LS138	Texas Instruments	2	
U13	Octal buffers/line drivers	SN74344	Texas Instruments	1	
U14-U16	Octal D-type latches	SN74373	Texas Instruments	3	
U17	Retriggerable Monostable multivibrator	SN74122	Texas Instruments	1	
U18-U23	Resistor networks - 22ohm	MDP1603-220G	Dale	13	
R1	10k-ohms± 10%; -.25 resistor			1	
C1	18 micro-F Tantalum capacitor	CSR 13G186K		1	
D1	Diode	1N4148	G.P.	1	
U31-U33	Octal line drivers	SN74S241	Texas Instruments	3	
TB1	7 post terminal strip	25-135-0753 Type 8145/7	Electrovert	1	
C2-C13	.1 micro-F Tantalum capacitor	CSR13G-104KL	Corning	12	
AL1	Audio alarm	SC6	Mallory	1	
U24-U27	Resistor network - 150ohm	MDP1603-151G	Dale	4	
U28-U30	Resistor network - 470ohm	MDP1603-471G	Dale	3	
J1-J4	Rear entry sockets 15 connectors	4030-15A	Molex	8	

PARTS LIST

NAWS Repeater L.E.D. PCB

Circuit Designation	Component Description	Part No.	Manufacturer	Qty.	Mil-Spec.
U1-U12	Red light bars	HLMP 2350	Hewlett-Packard	12	
U13-U24	Yellow light bars	HLMP 2450	Hewlett-Packard	12	
U25	Red bar graph	RBG 1000	Litronix	1	
U26	Yellow bar graph	YBG 1000	Litronix	1	
U27	Green bar graph	GBG 1000	Litronix	1	
U25-U27	green numeric display	HP5082-7633	Hewlett-Packard	3	
	Header strips				